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GENERALIZED EC&LSS COMPUTER PROGRAM CONFIGURATION CONTROL

Final Report

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MCDONNELL DOUGLAS CORPORATION

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GENERALIZED EC&LSS COMPUTER PROGRAM CONFIGURATION CONTROL

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FOREWORD

The work described in this report was performed by the Biotechnology Department of the Vehicle, Energy and Biotechnology Subdivision, Engineering Division, McDonnell Douglas Astronautics Company - West, Huntington Beach, California. Mr. J. R. Jaax of the Crew Systems Division, National Aeronautics and Space Administration, Johnson Space Center, Houston, Texas, was the contract monitor. S. W. Nicol was the project manager for McDonnell Douglas at Huntington Beach. The G189A computer program configuration control effort was performed on-site at NASA/JSC and was directed by R. L. Blakely with major assistance being provided by R. E. McEnulty.

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SUMMARY

This final report documents the work performed during Phase I of contract NAS9-14877, Generalized Environmental Control and Life Support System Computer Program (G189A) Configuration Control. Phase I of this contract covers the period from 15 November 1975 to 14 November 1976. During this period the following items of significance were accomplished:

1. The G189A simulation of the Shuttle Orbiter ECLSS was upgraded in the following areas:

   a. The G189A component model configuration was changed to represent the current PV102 and subsequent vehicle ECLSS configurations as defined by baseline ARS (5/27/76) and ATCS (7/16/76) schematics provided by RI (Reference 15). The diagrammatic output schematics of the gas, water, and freon loops were also revised to agree with the new ECLSS configuration.

   b. The accuracy of the transient analysis was enhanced by incorporating the thermal mass effects of the equipment, structure, and fluid in the ARS gas and water loops and in the ATCS freon loops. The source and approximate date of the data used to upgrade the simulation are listed below:

ATCS freon loop line sizes and lengths	Reference 32	2/10/75
ARS water loop line sizes and lengths	Reference 33	2/24/76
ARS water loop and ATCS freon loop component and equipment weights	Reference 34	11/2/75

ARS cabin and avionics bay thermal capacitance and conductance values | Reference 35 | 1/30/76

c. Two new subroutines were developed, REDDER & RITER, which select and store key parameter phase averaged data at the end of each phase and print out a summary comparison table of these data, listed by mission phase, at end of each simulation run. This summary comparison table provides a useful printout which can be used for "quick look" run assessments and for study report documentation. Figure 1 presents an example of this output.

d. The logic in subroutines ARSGAS, ARSH2Ø, FCL, and QPHAVG was modified to allow the data tapes, which contain phase averaged heat flux and temperature data from two previous analyses, to be automatically updated with the results of the current run.

e. The special Shuttle simulation master program library version which accepts phase average heat load data as table card input was modified to provide the option of running either a simulated transient (steady state solutions for each mission phase) or a true transient analysis of the input mission data.

2. A single G189A combination master program library tape was generated which contains all of the master program library versions which were previously maintained on separate tapes. This was made possible through the use special Univac 1108 Exec II system capabilities available at JSC. The details of this procedure are described below in Section 2.1.

3. A new component subroutine, PIPETL, was developed and incorporated into the G189A master program library. This subroutine is used to simulate the thermal mass effects and/or fluid transport lag effects for liquid flow in pipes, tables, and/or liquid loop circuits. (This subroutine was developed as a replacement for subroutine PIPE.)

4. Twenty-four of the existing G189A standard library version subroutines were revised during this report period. Revisions were made to the plot package subroutines to allow negative values of component V array data to be plotted and to provide a tabular printout of off-scale plot data when the plot limits are predefined on the plot request cards. Revisions were made to the format of the restart tape with "change case" runs. The new tape format stores the original basic case card image data and K and V array data at the beginning of the change case restart tape. (This allows recovery of the original basic data from a change case restart tape.) The other subroutine revisions were made to: (1) increase amount of storage available for simulation model data, (2) improve the error diagnostic capabilities of the program, (3) provide additional component subroutine capabilities, and (4) correct logic determined to be erroneous or inefficient.

5. Approximately 17 different G189A Shuttle Orbiter ECLSS simulation model configurations were generated during this report period (Table 1). Eleven study reports (References 16-24, 28, & 29) and two technical notes (References 25 & 31) were published.

1.0 INTRODUCTION

The G189 Generalized Environmental Control and Life Support System Computer was initially conceived and developed by MDAC-W in 1964. An initial version of the program was delivered to NASA/JSC in 1965 under contract NAS9-4090. Since 1965 a number of program additions, revisions, and new developments have occurred as a result of in-house work and subsequent NASA contracts. The Crew Systems Division (CSD) of NASA/JSC has been instrumental in developing this program into a valuable ECLSS simulation analysis tool. This contract, NAS9-14877 - Generalized Environmental Control and Life Support System Computer Program (G189A) Configuration Control, provides NASA/JSC with Houston based personnel who can maintain, update, and utilize the G189A computer program effectively and efficiently. The contract effort also includes: (1) providing instruction and consultation services for others regarding the use and application of the G189A program, (2) developing new subroutines or modifying existing subroutines to provide additional capabilities required for current or new simulations, (3) maintaining and improving existing G189A simulation models developed for Shuttle ECLSS and payload ECLSS analyses, (4) developing new simulation models as required, (5) supporting special study analyses requested by CSD, and (6) conducting studies to define and understand the design and off-design performance characteristics of the Shuttle ECLSS, its interaction with proposed payload ECLSS designs, and the effects of suggested ECLSS configuration changes. This contract continues the effort begun in April 1973 under contact NAS9-13404. The following section describes in detail the progress made under the various tasks described in the Phase I portion of contract NAS9-14877.

2.0 REPORT OF PHASE I PROGRESS

The Phase I progress on tasks 1-13 as described in contract NAS9-13404 is reported below.

2.1 Task 1, Formulate Master Programs

Four unique G189A master program library versions were prepared and maintained on the NASA/JSC, Univac 1108, Exec II computer system under Phase III of the preceeding configuration control contract (Reference 12). Each library version was stored on a separate master program library tape. A standard library version of the G189A program containing all of the generalized subroutines listed in the program manual (Reference 13) was maintained by general use and application. Three special Shuttle master program library versions were maintained for specific Shuttle simulation applications: (1) a Shuttle Orbiter ECLSS simulation model which reads a Mission Performance and Analysis Division (MPAD) generated electrical power profile data tape to determine the transient electrical heat loads imposed on the Shuttle ECLSS, (2) a Shuttle Orbiter plus payload ECLSS simulation which reads a MPAD electrical power profile data tape, and (3) a Shuttle orbiter ECLSS simulation model which uses card inputs to define phase averaged heat load data such as those generated by RI for the Power Statusing Mission Profile (PSMP) or the Typical Sortie Day (TSD) mission analysis. These four master program library version tapes were maintained and updated spearately for the first ten months of this contract period. However, this method of file maintenance proved to be inefficient, time consuming, and error prone because the contract effort generally required the use of one particular library version for an extended time period or for a special study analysis. This resulted in subroutine modifications being generated for one particular library version. Many library routines are identical for all versions, some are similar but not identical, and others are applicable only to a particular version; therefore, it was necessary to halt operations periodically and update each library version tape to reconcile it with the all subroutine modifications generated since the last library version tape update. An investigation of methods to be used for combining the various master program library versions onto a single library tape was initiated in October 1976 and resulted in the generation of a single G189A combination library tape which is described in the following paragraphs.

A single G189A combination master program library tape was generated on October 15, 1976, which contained all of the master program library versions discussed above. The creating of the G189A combination library tape utilized the Univac 1108 Exec II system capability to specify a subroutine symbolic set of code as an element NAME/VERSION and its corresponding relocatable element by a NAME/VERSION (FLAG). These features are described in detail on pages 19:30.02 and 19:60.03 of the NASA/JSC IDSD Procedures Manual (Reference 14). They provide a technique whereby many library subroutine versions can be maintained on a single PCF (master program library) tape and a flag (specified for the relocatable elements) can be used at execution time (on the XQT card) to select the subroutines that are to be allocated and run for a particular library version. The combination library tape greatly simplifies the update procedure because: (1) routines that are common to all versions can be modified by a single update process, (2) modifications to similar version-dependent subroutines can be easily accomplished by referencing a single PCF tape listing and by generating the required modifications for all element versions of a particular subroutine at the same time, and (3) version peculiar modifications can be generated and included in the current run deck without affecting its capability to execute any library version.

The element NAME/VERSION (FLAG) parameters used for the G189A combination master program library tape are defined below:

NAME — The Fortran name of the subroutine or function; e.g., ANYHX, GPØLY1, GASMIX, etc.

VERSION — A lable consisting of 1-6 alphanumeric characters which is appended to the element name and preceeded by a slash (/). The addition of unique version labels allows the PCF tape to contain more than one element with the same name; e.g., GPØLY1/M, GPØLY1/Q, GPØLY1/A. The version labels used for the combination tapes and their meanings are described below.

Version Label	Meaning
(no label)	A symbolic element that is used in all library versions.
CØDE	A relocatable element that is used in all library versions.
A	A symbolic element in the standard library version.
A1	A relocatable element in the standard library version.
M	A symbolic element in the Shuttle ECLSS simulation version library that reads the MPAD power profile data tape.
M1	A relocatable element in the Shuttle ECLSS simulation version library that reads the MPAD power profile data tape.
Q	A symbolic element in the Shuttle ECLSS simulation library that uses phase averaged heat load table input data.
Q1	A relocatable element in the Shuttle ECLSS simulation library that uses phase averaged heat load table input data.
S	A symbolic element that may be used in either Shuttle ECLSS simulation library version (M or Q).
S1	A relocatable element that may be used in either Shuttle ECLSS simulation library version (M1 or Q1).
FLAG	A string consisting of from one to 26 unique alphanumeric characters which is enclosed by parentheses and appended to the relocatable element version; e.g., GPØLY1/S1 (MQ), QLOAD/M (M), etc. One of these flag-letters may be specified on the XQT card of a run deck which causes all relocatable elements containing that flag letter to be loaded together with those relocatable elements which contain no VERSION (FLAG) appendages (See page 19:60.02 of Reference 14) to form an executable library version of the G189A program. The following

Version Label	Meaning
	flags were chose by library version selection from the G189A combination master program library tape.

Flag	Applicable Library Version
(no flag)	All library versions
A	Standard G189A library
M	Special Shuttle simulation library that read the MPAD power profile data tape.
Q	Special Shuttle simulation library that uses phase averaged heat load table input data.

The shuttle orbiter plus payload ECLSS library version was not retained as a separate library. However, an option was added to the M and Q flag versions which allows the simulation of the payload ECLSS to be included with the basic Shuttle orbiter ECLSS simulation if desired. The option code for the payload ECLSS simulation was placed in KK(4, 17) and is specified as follows:

KK(4, 17) = 0	Shuttle orbiter ECLSS simulation, Q flag library.
= 1	Shuttle orbiter plus payload ECLSS simulation, Q flag library.
= 2	Shuttle orbiter ECLSS simulation, M flag library.
= 3	Shuttle orbiter plus payload ECLSS simulation, M flag library.

The G189A combination master program library for the NASA/JSC, Univac 1108 Exec II computer system is stored on two identical JSC library tapes (X11286 and X16459) and were created on 10/15/76. Each tape contains two identical files of the combination library. A complete listing of the G189A combination master program library is maintained at NASA/JSC, Building 7A, Crew Systems Division.

An Exec 8 version of the G189A master program library was created and maintained for several months during this contract effort; however, this library could not be maintained because of system problems encountered and because of manpower limitations (References 8 and 10).

2.2 Task 2, Maintain Tape Library

A new format for documenting the tapes currently being maintained in the JSC tape library for G189A simulation model usage was established in August 1976 (Reference 9) and is enclosed herein as Table 1 - Shuttle Orbiter ECLSS Models.

Each G189A simulation model requires a particular configuration of a master program library tape, a simulation model data tape, and a MPAD power profile data tape or phase averaged heat load table card inputs. Table 1 lists all of the simulation models currently being maintained at NASA/JSC. Column 1 of Table 1 specifies an item number which is assigned sequentially for every simulation model developed and/or for every MPAD SEPS power profile data tape that is generated for G189A simulation usage. Column 2 contains the model description. Column 3 specifies the master program library tapes which must be used to execute the model, column 4 specifies the operational date of the library tapes, and column 5 specifies the drop date of the library tapes. (For simulation models created after October, 1976, the flag-letter that denotes the library version to be with the combination library tape at execution time is appended to the tape number in column 3.) Columns 6-8 contain the simulation model data tapes, their operational date and their drop date. A code is added after the tape number in column 6 to indicate if the data tape was created from a steady state analysis (SS) or a transient (Tr) analysis. If multiple tapes were generated notes are added under column 6 to indicate the time span or phase span of the data contained on the tape. Columns 9-11 specify the MPAD power profile data tape to be used for the model, its operational date, and its drop date. The MPAD source data base tape number that was used to generate the power profile tape is also listed in column 9 in parentheses just below the power profile data tape

number. For the models that utilize phase averaged heat load table data inputs, a note indicating "card inputs" has been specified in column 9 in place of a tape number; e.g., item 16, Table 1.

It may be noted under item 1 of Table 1, that the master program library tapes were dropped because they were obsolete or damaged. This model can still be run by using the most recently generated master program library tape; however, some modifications may be required for the new library tape and for the existing simulation data tape to insure compatability. If a simulation model data tape is damaged or if the model is invalid, obsolete or replaced by a more recent data set the item is crossed out and the reason indicated; e.g., items 5-7. Table 1 is revised periodically and the revised pages with revision dates and marks are published in the monthly progress reports.

In addition to the tapes noted in Table 1, a number of special purpose data comparison tapes are maintained. These tapes contain the computed results from two prior G189A simulations that utilized RI phase averaged heat load data table inputs. The data from these tapes are extracted and used to provide a three column comparison set of heat load and temperature data (Figures 1-3, Reference 12) for each mission phase. Columns 1 and 2 contain the results of the previous analyses carried on the data tape and column 3 contains the current simulation results. The comparison data tape numbers, creation date, mission, number of phases, and column 1 and 2 data descriptions are listed in Table 2 - Special Purpose Comparison Data Tapes.

2.3 Task 3, Provide Recommendations

Contact has been maintained between Karl Houck, NASA/JSC; Bill Ayotte, HSD; and Stuart Nicol, MDAC-W during this report period to provide them with recommendations regarding the use of master program library tapes, the use of simulation model data tapes, the modification of program subroutines to perform specific tasks, and peculiarities and limitations of selected subroutines. These personnel were the only identified active users of the G189A program during this report period.

2.4 Task 4, Provide Instruction

Consultation services have been provided for the on-site users of the G189A program and telephone communications have been maintained with the off-site users to provide them with information regarding new program features and options, subroutine revisions, program manual changes. This data has also been documented in the monthly progress reports (References 1-11).

2.5 Task 5, Provide Program Modifications

During this report period modifications were made to 21 of the subroutines that are used by all of the library versions, to 4 of the subroutines that are used only in the standard library version, and to 24 of the subroutines used for the Shuttle library versions. The modifications made to each subroutine have been documented in the monthly progress reports and are referenced below for each subroutine name/version (Section 2.1).

Subroutine NAME/VERSION	Reference Document, Reference No. (Section)
ANYHX	1 (1.5)
ARSGAS/S	1 (1.5), 3 (1.5.1)
ARSH2Ø/S	3 (1.5.1), 9 (1.4), 11 (1.4.1)
ARST/S	1 (1.5), 3 (1.5.1, 1.5.3), 9 (1.4), 10 (1.4)
ATCST/S	1 (1.5), 3 (1.5.1, 1.5.3), 5 (1.4), 9 (1.4), 10 (1.4)
CABIN/S	11 (1.4.1)
CABINT/S	10 (1.4)
CMAN	3 (1.5.2), 4 (1.4.1)
CØMSØL/S	6 (1.3.1), 11 (1.4.1)
ECLST/A	1 (1.5), 4 (1.4.1), 5 (1.4), 6 (1.3.1), 9 (1.3)
ECLST/S	1 (1.5), 9 (1.4), 11 (1.4.1)
ELINT/M	3 (1.5.1), 10 (1.4), 11 (1.4.2)
ELØAD/M	3 (1.5.1), 11 (1.4.2)
EFFCP	9 (1.3)
ELCØØL	10 (1.4), 11 (1.3.2)
FAN	10 (1.4)

Subroutine NAME/VERSION	Reference Document, Reference No. (Section)
FCL/S	3 (1.5.1, 1.5.3), 9 (1.4), 11 (1.4.1)
FLØSUM	9 (1.3)
F21/S	1 (1.5), 4 (1.4.1)
GPØLY1/A	4 (1.4.1)
GPØLY1/M	3 (1.5.1), 4 (1.4.2), 10 (1.4), 11 (1.4.2)
GPØLY1/Q	3 (1.5.3), 4 (1.4.4), 6 (1.3.2), 9 (1.4), 11 (1.4.3)
GPØLY2/A	4 (1.4.1)
GPØLY2/M	3 (1.5.1), 4 (1.4.2, 1.4.3), 6 (1.3.1), 11 (1.4.2)
GPØLY2/Q	3 (1.5.3), 4 (1.4.4), 6 (1.3.2), 9 (1.4), 11 (1.4.3)
G189	9 (1.4)
IEDIT	4 (1.4.1), 9 (1.3)
KVREAD	5 (1.4), 6 (1.3.1)
MAINPL	4 (1.4.1)
MERGEC	4 (1.4.1)
PIPETL	6 (1.3.1), 11 (1.3.2)
PLEDIT	4 (1.4.1), 11 (1.3.2)
PLØT89	1 (1.5), 4 (1.4.1)
PUMP	10 (1.4)
QLØAD/M	3 (1.5.1), 4 (1.4.3), 10 (1.4), 11 (1.4.2)
QPHAVG/S	3 (1.5.1), 4 (1.4.3), 5 (1.4), 9 (1.4), 10 (1.4), 11 (1.4.1)
QTAVG/S	1 (1.50, 3 (1.5.1), 4 (1.4.3), 9 (1.4), 11 (1.4.1)
REDDER/S	5 (1.4), 9 (1.4)
RITER/S	5 (1.4), 9 (1.4), 11 (1.4.1)
R718/S	1 (1.5), 4 (1.4.1)
SCRUP	6 (1.3.1)
SEGPRG/S	11 (1.4.1)
SHIRTS	3 (1.5.2), 4 (1.4.1)
STØPIT	5 (1.4)
TABLRD	10 (1.4)
TAPEIT/A	4 (1.4.1), 10 (1.4)
TAPEIT/S	3 (1.5.3), 4 (1.4.2), 9 (1.4), 10 (1.4), 11 (1.4.1)
UWIN	4 (1.4.1), 9 (1.3)
VARPRT	1 (1.5), 4 (1.4.1)

2.6 Task 6. Establish System Schematics

Specific G189A program system configurations are generally prepared for each G189A simulation model. These configurations consist of a master program library tape; a simulation basic case data tape; and, in the case of Shuttle Orbiter ECLSS simulations, special purpose data tapes such as the MPAD power profile data tapes and the phase averaged heat load and temperature comparison data tapes. The system configurations currently maintained under this contract are listed in Table 1 which was discussed in Section 2.2. This task also requires the preparation of G189A system configurations for other users. This was done for Karl Houck, NASA/JSC, for the Shuttle EMU model and for Bill Ayotte, HSD, for the RLSE model.

2.7 Task 7. Provide Digital Computer Program Requirements

Program listings of the G189A master program library tapes (Table 1) and card decks for the execution of current simulation models are maintained at NASA/JSC, building 7A, CSD. The master program library tapes, simulation model data tapes, MPAD electrical power profile data tapes, and phase averaged comparison data tapes are stored in the NASA/JSC Institutional Data Systems Division (IDSD) magnetic tape library in building 12. The G189A ETC/LSS program manual (Reference 13) updates, prepared during this contract effort, are included as Attachment A of this report.

2.8 Task 8. Support Special Analyses

The following special study analyses were made or supported during this contract effort:

1. A G189A transient simulation of a captive flight test of the OV101 Shuttle Orbiter ECLSS was prepared and run (Table 1, item 1) and the results of the case were documented in a study report (Reference 16).

2. A G189A transient simulation of the OV102 Shuttle Orbiter for the OFT-6 Mission was prepared and run (Table 1, item 5) and the results were transmitted informally to J. R. Jaax.

3. A G189A transient simulation of the OV103 Shuttle Orbiter ECLSS was run for the Baseline Reference Mission 2 with a 29,000 Btu/hr payload (Table 1, item 6) and the results were documented in a study report (Reference 17).

4. The item 3 model listed above was modified to study the effects of a high cabin wall leak in combination with a 40°F radiator outlet temperature during the Sortie operations day 1 and 2 phases. The results of the study were documented in Reference 18.

5. A G189A steady state simulation of the OV103 Shuttle Orbiter ECLSS was prepared and run using the RI 11-5-76 Power Statusing Mission Profile (PSMP) heat load data and the results were transmitted informally to J. R. Jaax.

6. The item 4 model listed above was modified to study the effects of using an OV101 interchanger and/or cabin heat exchanger design on OV103. The results were compared to the item 4 data in a study report (Reference 19).

7. A G189A steady state simulation of the OV103 Shuttle Orbiter ECLSS was prepared using RI 1-16-76 Seven Day Mission Power Profile heat load data. This simulation was run for a series of cases to determine the OV103 critical cabin air condensing heat exchanger design conditions (Reference 20), to access the current performance status of the Orbiter ECLSS for all mission phases under RI maximum heat load conditions (Reference 21), and to study the effect of repositioning one freon loop flow diverter valve to provide maximum payload cooling during all mission phases (Reference 22).

8. A G189A steady state simulation model of the OV103 Shuttle Orbiter ECLSS was prepared using RI 1-16-76 Case 8 Typical Sortie Day (TSD) heat load data. The simulation was run for a series of cases to determine the ECLSS performance for the 11 new subphases provided by the RI TSD data, to study the effect of using OV101 interchanger

and cabin heat exchanger design on OV103, and to evaluate the effects of using HS-C as a replacement for LIOH to remove carbon dioxide from the cabin air. The results of these cases were transmitted informally to J. R. Jaax and Dave Kissinger.

9. A G189A transient simulation of the OV103 Shuttle Orbiter ECLSS was prepared for reading a special 6 hr OV103 simulation MPAD power profile data tape (Table 1, item 12). This simulation was used to run a series of cases to study the effect of repositioning one Freon loop flow diverter valve to provide maximum payload cooling during all mission phases (Reference 23) and to compare the MPAD power profile data and analyses to the RI 1-16-76 data and analysis. The results of the latter runs were transmitted informally to J. R. Jaax.

10. A study of the history and effects of the Shuttle Orbiter heat load growth upon the ECLSS performance was made beginning with the ECLSS proposal data and using the results of G189A simulations for subsequent performance. The results of this study were documented in Reference 24.

11. A technical note (Reference 25) was prepared describing the ramifications of changing the RI Electrical Equipment List (EEL) component numbers for each vehicle and for each update of the RI power data because these numbers are used in the MPAD source data base to generate the MPAD power profile tapes which are ready by the G189A program.

12. A G189A steady state simulation of the OV103 Shuttle Orbiter ECLSS was prepared to evaluate two emergency return power profiles: (1) a 24 hour emergency return - nominal ARS heat loads with single string avionics developed by RI, and (2) a 24 hour minimum power return - nominal ARS heat loads developed by NASA. Both single Freon loop and dual Freon loop operation cases were run for both power profiles and the results were trasmitted informally to J. R. Jaax.

13. A set of equations were developed for the Wang computer which would determine the cabin condensing heat exchanger inlet dew points for selected test conditions representative of the Shuttle Orbiter cabin heat loads and water temperature and flow at the heat exchanger inlet.

14. A Cabin and ECLSS Cooled Equipment Study (Reference 26) was initiated by CSD in June 1976. The following tasks have been completed in support of this study.

    (1) The RI June 21, 1976, Typical Sortie Day (TSD) electrical equipment utilization data were modified to agree with the JSC MPAD electrical equipment utilization notes (Reference 27) and a new set of ARS heat load data were generated (Reference 28).

    (2) The RI June 2, 1976, Rev. 2 Power Statusing Mission Profile (PSMP) electrical equipment utilization data were also modified to agree with the JSC MPAD electrical equipment utilization notes and a new set of ARS heat load data were also generated (Reference 29).

    (3) A G189A simulation of the OV103 Shuttle Orbiter ECLSS was prepared which could utilize the heat load data generated under items 13(1) and 13(2) above and was capable of performing both steady state and transient analyses. The Cabin and ECLSS Cooled Equipment Temperature Study data (Reference 26) defined eight cases to be run and a G189A model simulation was developed for each of these (Table 1, items 21 and 23-29). All eight of these cases have been run using the steady state phase analysis technique and two of the cases (Case 6 - TSD and Case 8 - PSMP) were run using a transient analysis technique. The computed results from these runs have been transmitted to J. R. Jaax and to RI (Reference 30).

15. A G189A transient simulation of the Spacelab 1 Shuttle Orbiter ECLSS was prepared which reads an MPAD power profile data tape prepared specifically for the Spacelab 1 mission (Table 1, item 30). This model was run and the computed results have been transmitted to J. R. Jaax.

16. G189A simulations of the OV103 Shuttle Orbiter ECLSS are currently being prepared for analyzing two new sets of phase averaged heat load data received from RI: (1) Powered down entry - single string (design baseline) 9-27-76 and (2) Power down entry - single failure tolerant (study only) 9-27-76.

2.9 Task 9, Shuttle Orbiter ECLSS Model

Numerous Shuttle Orbiter ECLSS models have been prepared during this contract effort to perform special studies, analyze new sets of RI phase average heat load data, analyse new MPAD power profile data, and to reflect changes in the Shuttle Orbiter ECLSS configuration. The simulation models that are currently being maintained under this contract are listed in Table 1.

2.10 Task 10, Provide Shuttle Electrical Load Data Base

The master program library subroutines ELINT/M, ELØAD/M, and QLØAD/M were modified for each simulation model which utilized a MPAD power profile data tape. These modifications were required because of EEL component number changes which occurred between vehicles and power profile data tape releases (Reference 25). The current MPAD version of the EEL dictionary and the associated heat load summing equations are incorporated in the master program combination library tape routines listed above and some of the older versions are maintained as card decks. The MPAD power profile data tapes which are currently available for analysis are listed in Table 1.

2.11 Task 11, Provide Study Reports

Eleven study reports (References 16-24, 28 and 29) and two technical notes (References 25 and 31) were prepared during this contract effort. The study analyses which generated these reports are discussed above under Section 2.8.

2.12 Task 12, Provide Monthly Progress Report

Eleven monthly progress reports (References 1-11) were provided under this contract effort.

2.13 Task 13, Final Report

This document is furnished to satisfy the requirements of Task 13.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The G189A program configuration control contract has proved to be an efficient method of organizing and controlling the use and modification of the G189A program and the G189A simulation models. The program users have been identified and communications have been maintained with these users to provide consultation, determine program errors and deficiencies, identify new requirements, and define system configurations to be used for specific problem solutions. This effort has resulted in the orderly development of the G189A program and has established a central authority who can assess proposed program changes and their effects upon the program's generalized applications. Specific simulation model requirements are accommodated by creating special versions of the standard G189A master program library (Section 2.1). As these modifications are checked out and used and if they are determined to be applicable to other simulations or to the standard master program library their solutions are prepared as generalized logic blocks which can be added to other library versions and/or to the standard library version. The generation of special master program library versions has complicated the program maintenance and updating procedures but it provides more efficient simulations that minimize core storage requirements and it prevents simulator peculiar logic from being erroneously incorporated into the standard library version used for generalized applications. A technique was developed during the latter portion of this

report period whereby all of the various master program library versions could be placed on and accessed from a single master program combination library tape (Section 2.1). This development alleviated many of the problems encountered and the man hours required previously for the maintenance of separate tapes for each library version.

The G189A Shuttle Orbiter ECLSS simulation models developed under Phase III of the previous contract (Reference 12) were modified and upgraded to provide new simulation model configurations required for the studies performed under this contract (Section 2.8). A simulation model log was developed (Table 1) which identifies the various simulation model configurations developed and their current status. This log provides a convenient method of assessing the current G189A Shuttle ECLSS analysis capability.

The Shuttle simulation models were used extensively during the past year to provide total system performance assessments for the Shuttle Orbiter ECLSS. Steady state mission phase analysis using phase averaged heat load data generated by RI or NASA were used to provide quick turn-around results for various study efforts. The steady state mission phase analysis models were modified this year to provide a transient analysis capability so that studies could be performed to evaluate the transients which occur at the start of each new phase and the transient performance effects of short duration phases which do not reach steady state. RI has begun to publish phase average heat load data for a typical Sortie Day (TSD) which subdivides a Power Statusing Mission Profile (PSMP) 24 hour sortie day phase into 11 subphases. The new transient analysis capability incorporated into the phase averaged heat load data simulation models provides more realistic system performance responses for TSD subphase data and also for the short duration ascent and descent phases of the PSMP. This capability has also been useful in resolving the differences which had previously occurred between the transient analyses of the MPAD electrical power profile data and the steady state analyses of the RI phase averaged heat load data.

The simulation models which utilize the MPAD electrical power profile data as input provide a true transient ECLSS performance analysis tool that responds to the instantaneous power level changes which occur in an actual mission. These models and those discussed above have been revised this year to include the liquid loop transport lag effects and the thermal mass effects of the fluids, equipment, and structure associated with the ECLSS. These revisions have resulted in more accurate transient performance predictions; however, the simulated mission time to computer execution time ratio has decreased to a value of $\sim$ 33/1. This ratio is still very attractive considering the capabilities of the model and the fact that the entire ECLSS can be simulated with a single run that uses transient electrical power data.

The phase averaged heat load input models have been used for most of the study efforts performed this year because of the availability of data, the quick response capability, and the minimization of computer time. These models are usually run to provide steady state solutions for each phase and require $\sim$ 15 minutes of Exec II computer time for a 11 phase TSD mission analysis and $\sim$ 20 minutes for a 23 phase PSMP mission analysis. These analyses appear to be adequate for investigating the OV103 Shuttle Orbiter ECLS design and off-design performance for the generalized mission model that is currently available. The transient capabilities of these models can be used to study particular problems observed from the TSD and PSMP steady state analyses results and/or long duration phases can be subdivided further to provide a more realistic simulated transient analysis. Specific mission analyses (e.g., Spacelab 1, Table 1, item 30) will require the use of the MPAD power profile data input models because trajectories, mission timelines, and payload pecularities greatly influence the ECLSS boundary conditions and an accurate transient analysis is required. Therefore, as vehicle configurations and mission timelines become better defined the G189A simulation model usage will shift more towards the use of the MPAD power profile data tape models which require more preparation but are much more accurate for detailed transient analysis.

The G189A Shuttle simulation models have proven to be a very cost effective method of studying overall ECLSS performance under a variety of conditions. Problem areas can be quickly identified and determinations can be made as to the necessity of performing additional analyses requiring the use of the detailed thermal analyzer models which are prepared and maintained by RI. The ease and speed with which special ECLSS reconfigurations, failure modes, and/or boundary conditions can be incorporated in the various models has been thoroughly demonstrated. The present set of G189A Shuttle Orbiter ECLSS simulation models provides a varied data base which can easily be upgraded and/or modified to accept hardware development and acceptance test data as they become available.

The following recommendations are made with regard to desired improvements for the G189A program and the Shuttle simulation models:

1. Modifications should be made to the G189A plot package routines to provide the capability of generating a plot tape that could be post-processed by a separate program and/or an option should be provided whereby plots would automatically be generated for every 500 data records saved. (The current plotting package is limited in the number of data records that can be plotted due to drum storage limitations and raster count resolution of the CRT unit used for the plot display). The plot tape/post processer program would allow (1) recovery of the plot data for run terminated by systems errors, (2) the tabular results to be verified before plot data processing, (3) the selection of a specific range or group of data points to be plotted for detailed problem area studies and would not require a rerun of the simulation model and (4) eliminate the loss of data records because of storage limitations. The automatic plotting option would process the plot data during the simulation model execution and would prevent the loss of data records caused by storage or CRT limitations.

2. A new subroutine should be developed that allow a component's K array data to be printed out. (The G189A library currently contains subroutines which print out component A, B, R, and V array data.) This routine would be useful for model debugging.

3. All obsolete, undocumented and unused subroutines should be eliminated from the Master Program Library and their documentation should be deleted from the program manual.

4. The advantages and disadvantages of maintaining the G189A program and simulation models on the Exec 8 system should be studied further. If the file management, system reliability, manpower, and tape drive limiation problems can be solved; then the program and models should be converted.

5. The transient G189A simulation models should be analyzed to determine what improvements could be made to decrease computer time requirements. One possibility may be the creating of a new subroutine to simulate the heat transfer characteristics of the avionics bay air cooled equipment. (The CABIN subroutine is presently used; however, the detailed gas constituent calculations performed in the CABIN subroutine are not required for present analysis.)

6. The program that generates the EEL component number dictionary for the G189A simulation models that access MPAD power profile data tapes should be modified to operate on the MPAD source data base which is applicable to all vehicles and missions. (The present program operates on a MPAD SEPS data tape which is valid for only one particular mission. Therefore, an EEL dictionary must be generated for each new power profile data tape.)

7. The thermal mass, heat transfer conductance, fluid line size and length data incorporated into the Shuttle Orbiter ECLSS models this year should be updated and, if possible, the predicted transient responses of the water and freon loops should be verified by test data.

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21. G189A Simulation of OV103 Using RI 1/16/76 Orbiter 7 Day Mission Power Profile, Study Report No. 76-MDAC-W-AJCO-6, R. L. Blakely to J. R. Jaax, 2 March 1976.

22. Effect of Repositioning One Freon Loop Flow Diverter Value to Provide Maximum Payload Heat Exchanger Freon Flow During All Mission Phases - Steady State Analysis, Study Report No. 76-MDAC-W-AJCO-7, R. L. Blakely to J. R. Jaax, 3 March 1976.

23. Effect of Repositioning One Freon Loop Flow Diverter Value to Provide Maximum Payload Heat Exchanger Freon Flow During All Mission Phases - Transient Analysis, Study Report No. 76-MDAC-W-AJCO-8, R. L. Blakely to J. R. Jaax, 12 March 1976.

24. Chronological History and Effects of the Shuttle Orbiter Heat Load Growth Upon ECLSS Performance, Study Report No. 76-MDAC-W-AAJO-9, R. L. Blakely to J. R. Jaax, 10 April 1976.

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32. Informal data transmittal, Elton Kincaide (RI) to Al Behrend (EC2), 2-10-75 (ATCS configuration with GSE bypass line and proportioning flow control valve.)

33. Informal data transmittal, Joe Chamblis (LEC) to R. L. Blakely (MDAC), Computer printout of RI OV103 water loop model for THAP (Wilkinson's model) run on 2-24-76.

34. RI Control Book Mass Properties Orbiter OV103, 11-2-76 tab run, Shuttle Operation Data Submittal S-227, Ray Hischke to R. L. Blakely, 12-11-75.

35. Informal data transmittal - Summary of Capacitance & Conductance Values from Simplified Cabin ECLSS Program (Ref. IL SEH-ITA-76-026, 30 January 1976), Maury Upthagrove (RI) to R. L. Blakely (MDAC).

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TABLE 1 SUMMARY COMPARSION OF PHASE AVERAGED DATA

6189A SHUTTLE ECLSS -SINGLE FAILURE TOLERANT 9/27/76 DATE 041176

MISSION PHASE:	18	19	20	21	22	23
DESCRIPTION:	DEORBT PREP	FINAL PREP	DEORBT BURN	ENTRY	DSCENT	FINAL APPRCH
DURATION:	02H 00M 00S	01H 00M 00S	00H 43M 28S	00H 30M 12S	00H 03M 16S	00H 02M 39S
NO OF MEN IN CABIN	7	7	7	7	7	7
1-HEAT LOADS (BTU/HR)						
CABIN AIR SENSIBLE						
AV. BAY LEAK	240.	351.	351.	351.	351.	351.
WALL LOAD	775.	775.	1571.	1571.	1571.	5000.
METABOLIC	2245.	2133.	1842.	1752.	1791.	598.
ELECTRICAL	1020.	1353.	1464.	1434.	1464.	1464.
TOTAL	4280.	4612.	5248.	5136.	5177.	7413.
CABIN H/X	12160.	12910.	13829.	13812.	13823.	17227.
ARS INTERCHANGER	25953.	29293.	31318.	31367.	32053.	35462.
PAYLOAD H/X	5200.	5200.	5200.	5200.	5200.	5200.
FUEL CELL H/X	22361.	26589.	24684.	24967.	28870.	28999.
ECLSS HEAT SINK	59002.	66989.	67449.	70239.	76423.	80837.
2-ELECTRICAL POWER (KW)						
PAYLOAD	1.0	1.0	1.0	1.0	1.0	1.0
TOTAL VEHICLE	12.2	14.0	13.2	13.3	15.0	15.0
AVAIL. F/C H2O (LB/HR)	7.3	8.9	8.2	8.3	9.8	9.8
3-TEMPERATURES (F)						
CABIN-DRY BULB	70.4	71.9	75.9	77.1	76.6	92.8
-DEW POINT	50.4	50.3	51.1	52.9	52.2	57.0
COND HX-AIR OUT	47.0	46.5	46.7	48.0	47.8	50.9
-AIR IN	124.1	107.5	111.7	113.0	112.4	129.7
ARS I/C-H2O OUT	40.3	39.6	39.5	41.5	40.7	42.2
-H2O IN	76.0	78.7	79.9	80.0	80.7	80.7
IMU H/X-AIR OUT	71.8	71.6	72.0	73.0	72.6	75.3
-AIR IN	114.3	114.0	114.5	115.6	115.1	118.1
AV. BAY 1-AIR SUPPLY	70.9	73.0	73.2	73.3	73.4	73.4
-AIR RETURN	69.6	99.4	101.1	101.1	101.3	101.3
-C/P H2O OUT	81.7	86.2	86.2	86.2	86.7	86.8
AV. BAY 2-AIR SUPPLY	70.7	72.8	73.0	73.0	73.2	73.2
-AIR RETURN	68.9	98.6	100.4	100.4	100.6	100.6
-C/P H2O OUT	80.6	84.8	84.6	84.7	85.4	85.4
AV. BAY 3-AIR SUPPLY	66.0	66.2	66.0	66.0	66.1	66.1
-AIR RETURN	67.4	67.6	66.9	66.9	67.0	67.0
-3B C/P H2O OUT	69.1	69.3	69.2	69.2	69.3	69.3
-3A C/P H2O OUT	71.7	72.1	71.8	71.9	72.7	72.8
P/L H/X-P/L FLUID SUPPLY	42.5	41.5	40.9	42.6	41.9	42.1
-P/L FLUID RETURN	103.2	102.3	84.6	86.2	85.5	85.7
FCL-AFT BODY C/P OUT	58.2	60.4	60.7	62.6	60.8	62.9
-MID BODY C/P OUT	77.2	79.2	77.1	79.6	79.6	84.3
-HEAT SINKS IN	87.9	93.3	88.4	90.4	92.9	96.0
-HEAT SINKS OUT	40.0	39.0	39.0	39.0	37.0	37.0

FIGURE 1 - SAMPLE OF SUMMARY COMPARISON TABLE FOR PHASE AVERAGED DATA

TABLE 1 - SHUTTLE ORBITER ECLSS MODELS

Item No.	Simulation Model Description	MASTER PROGRAM LIBRARY Tape No.	Oper. Date	Drop Date	SIMULATION DATA Tape No.	Oper. Date	Drop Date	SEPS POWER DATA Tape No.	Oper. Date	Drop Date
1	CASE 16 - OV101, FOD PROFILE 1 (Captive - Active, 2 Abort), Transient Orbiter ECLSS	~~V09955~~ ~~V11145~~	10-24-75	10-20-76	V00469	11-11-75		V14437 (V09279)	6-25-75	
2	OV101, FOD PROFILE 2 (2-Flare, Manual)							V14354 (V09279)	6-24-75	
3	OV101, FOD PROFILE 3 (25 Degree Offset, Auto)							V01615 (V09279)	6-25-75	
4	OV101, 3 Hr Active Captive Mission							V14899 (V09279)	6-25-75	
5	CASE 14 - OV102, OFT-6, 0-60° Y-POP, + XV̄, 38° RAD, Transient Orbiter ECLSS, 7-17-75 EEL, April '75 Use Notes	V09955 V11145	10-24-75	10-20-76 OBSOLETE	V06936	10-22-75	10-20-76	V13155 (V10553)	11-12-75	
6	CASE 15 - OV103, SRP2, 0-60° Y-POP, + XV̄, 38° RAD, 7-17-75 EEL, April 75 Use Notes, Transient Orbiter ECLSS	V08933 V08923	10-24-75	4-15-76 OBSOLETE	V10630	10-24-75	8-12-76	X11104 X11105 (V14123)	10-24-75 8-20-75	8-12-76
7	OV102, OFT-1, 7-17-75 EEL, April '75 Use Notes			REPLACED BY ITEM 13				V16029 (V10553)	11-12-75	
8	OV102, OFT-2, 7-17-75 EEL, April '76 Use Notes							V14629 (V10553)	11-12-75	
9	OV102, OFT-3, 7-17-75 EEL, April '75 Use Notes			REPLACED BY ITEM 14				V02136 (V10553)	11-12-75	
10	OV102, OFT-4, 7-17-75 EEL, April '75 Use Notes			REPLACED BY ITEM 15				V09813 (V10553)	11-12-75	
11	OV102, OFT-5, 7-17-75 EEL, April '75 Use Notes							V03120 (V10553)	11-12-75	
12	CASE 18 - OV103, 6 Hr Ascent, Jan '76 OV102 EEL, April '75 Use Notes, Transient Orbiter ECLSS	X07501 X07534	5-6-76	10-20-76 OBSOLETE	X04984	5-6-76	10-20-76	X11106 X11107 (V10553)	3-24-76	
13	OV102, OFT-1, Jan '76 EEL, April '75 Use Notes (Update to Item 7)			REPLACED BY ITEM 20				X11431 (X11237)	3-26-76	

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TABLE 1 - SHUTTLE ORBITER ECLSS MODELS

Item No.	Simulation Model Description	MASTER PROGRAM LIBRARY Tape No.	Oper. Date	Drop Date	SIMULATION DATA Tape No.	Oper. Date	Drop Date	SEPS POWER DATA Tape No.	Oper Date	Drop Date
14	OV102, OFT-2, Jan '76 EEL, Apr '75 Use Notes (Update to Item 9)							X11238 (X11241)	3-26-76	
15	OV102, OFT-14, Jan '76 EEL Apr '75 Use Notes, (Update to Item 10)							X10853 (X09863)	4-12-76	
16	NASA 24 HR CASE - OV103, Minimum Power Return, 4-8-76 Heat Load Data, Steady State Orbiter ECLSS	~~X05983~~ ~~X12078~~	5-13-76	10-20-76	X12021	5-12-76		(Card Inputs)		
17	RI 24 HR CASE - OV103, Minimum Power (Single String) Return, 4-15-76 Heat Load Data, Steady State Orbiter ECLSS	~~X05983~~ ~~X12078~~	5-13-76	10-20-76	V13671	12-9-75	8-1-76	(Card Inputs)		
18	~~RI CASE 6 - OV103, Max~~ Heat Loads, 1-16-76, 7 Day Mission, Steady State Orbiter ECLSS	X05983 X12078	5-13-76		X02448	5-24-76		~~(Card~~ Inputs)		
		REPLACED BY ITEMS 24, 27, 29								
19	~~RI CASE 8 - OV103, Max Heat~~ Loads, 1-15-76, Typical Sortie Day, Steady State Orbiter ECLSS	X05983 X12078	5-13-76		X00755	5-26-76		~~(Card~~ Inputs)		
		REPLACED BY ITEMS 21, 23, 25, 26								
20	OV102, OFT-1, Jan '76 EEL, July '76 Use Notes (Update to Item 13)							X09089 (X09110)	7-13-76	
21	CASE 2 - CABIN & ECLSS Cooled Equipment Temp. Study, RI TSD Maximum 6-21-76 Heat Load Data, No Shades Steady State and Transient Orbiter ECLSS	~~X13878~~ ~~X14037~~	7-27-76	10-20-76	X15318(SS)	8-18-76		(Card Inputs)		
22	~~OV103, Spacelab-1, Jan '76 OV102 EEL, July '76 Use Notes~~	~~X11443~~ ~~X11478~~	~~9-9-76~~					X13271 (X11761)	8-4-76	
			REPLACED BY ITEM 30							
23	CASE 6 - Cabin & ECLSS Cooled Equip. Temp. Study, RI TSD (Max) 6-21-76 Heat Load Data, Top Shades, SS or Transient Orbiter ECLSS	~~X13878~~ ~~X14037~~	7-27-76	10-20-76	X15347(SS) X08533(Tr)	8-18-76 10-21-76		(Card Inputs)		
24	CASE 4 - Cabin & ECLSS Cooled Equip. Temp. Study, RI PSMP (Max) 6-1-76 Rev 2 Heat Load Data, No Shades, SS or Transient Orbiter ECLSS	~~X13878~~ ~~X14037~~	7-27-76	10-20-76	X15108(SS)	8-19-76		(Card Inputs)		

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TABLE 1 - SHUTTLE ORBITER ECLSS MODELS

Item No.	Simulation Model Description	MASTER PROGRAM LIBRARY Tape No.	Oper. Date	Drop Date	SIMULATION DATA Tape No.	Oper. Date	Drop Date	SEPS POWER DATA Tape No.	Oper. Date	Drop Date
25	CASE 5 - Cabin and ECLSS Cooled Equipment Temperature Study, RI TCD (Nom.) 6-21-76 JSC Modified Heat Load Data, All Shades, 7 Men, SS or Tr Orbiter ECLSS	~~X13878~~ ~~X14037~~	7-27-76	10-20-76	X11759(SS)	8-21-76		(Card Input)		
26	CASE 1 - Cabin & ECLSS Cooled Equipment Temperature Study, RI TCD (Nom.) 6-21-76 JSC Modified Heat Load Data, All Shades, 4 Men, SS or Tr Orbiter ECLSS	~~X13878~~ ~~X14037~~	7-27-76	10-20-76	X01594(SS)	8-24-76		(Card Input)		
27	CASE 8 - Cabin & ECLSS Cooled Equipment Temperature Study, RI FCMP (Max) 6-1-76 Rev 2 Heat Load Data, Top Shades, 7 Men, SS or Tr Orbiter ECLSS	~~X13878~~ ~~X14073~~	7-27-76	10-20-76	X09687(SS) (Phases 1-25) X17045(Tr) (Phases 1-8) X17013(Tr) (Phases 9-12) X17032(Tr) (Phases 16-25)	9-9-76 10-18-76 10-19-76 10-19-76		(Card Input)		
28	CASE 3 - Cabin & ECLSS Cooled Equipment Temperature Study, RI FCMP (Nom.) 6-1-76 Rev 2 JSC Modified Heat Load Data, All Shades, 4 Men, SS or Tr Orbiter ECLSS	~~X13878~~ ~~X14037~~	7-27-76	10-20-76	X14084(SS)	8-30-76		(Card Input)		
29	CASE 7 - Cabin & ECLSS Cooled Equipment Temperature Study, RI FCMP (Nom.) 6-1-76 Rev 2 JSC Modified Heat Load Data, All Shades, 7 Men, SS or Tr Orbiter ECLSS	~~X13878~~ ~~X14037~~	7-27-76	10-20-76	X03560(SS)	8-30-76		(Card Input)		
30	OV103, SPACELAB 1, Jan '76 OV102 EEL, July '76 MPAD Use Notes	X04952(M) X16607(M) X11286(M) X16459(M)	10-5-76 10-15-76		X04291 (Tr) (Phases 1-9) X04668 (Tr) (Phases 10-12) X01940 (Tr) (Phases 13-19)	10-8-76 10-13-76 10-15-76		X07896 X13271 (X11761)	8-4-76 8-4-76	

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TABLE 2 - SPECIAL PURPOSE COMPARISON DATA TAPES

Tape No.	Creation Date	Mission	Number of Phases	Column 1 Data Description	Column 2 Data Description
X07365 & X12656	7-27-76	Power Statusing Mission Profile (PSMP), 8 Panel Radiator	23	RI Baseline PSMP Heat Load Data - April 1974	RI PSMP Data - January 1975
X01799	8-19-76	PSMP, 8 Panel Radiator	25		RI PSMP 6-1-76 Rev. 2 Heat Load Data Modified to Case 4, Cabin and ECLSS Cooled Equipment Temperature Study (Reference 15)
X15316	8-24-76	Typical Sortie Day (TSD), 8 Panel Radiator	11		RI TSD (Max.) 6-21-76 Heat Load Data Modified to Case 2 (Reference 15)
X09632	9-7-76	PSMP, 8 Panel Radiator	25		RI PSMP 7-1-76 Rev 2 Heat Load Data Modified to Case 8 (Reference 15)
X07950	10-21-76	TSD, 8 Panel Radiator	11		RI TSD (Max) 6-21-76 Heat Load Data Modified to Case 2 (Reference 15)